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Oderly accumulation theory of shale system petroleum resource and its prospecting significance- A case study of Chang 7 Member of Yanchang Formation in Ordos Basin

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1 Introduction

Shale formations bear abundant mineral resource and* unconventional petroleum resource, and the unconventional petroleum resource that contain in the shale formation should be integrated and researched. Apart from the conventional petroleum resource, shale formations bear abundant mineral resource and unconventional petroleum resource, which include fractured mudstone reservoir, tight oil, shale hosted oil, shale hosted gas, tight gas and oil shale, all of which have been confirmed. According to the difference of the reservoir space, shale system can be divided into fractured shale, shale that bears permeable inter layer and matrix mud shale, the correspondence of which are fractured mudstone reservoir, tight oil and gas and shale hosted oil and gas respectively. Fractured reservoir, that is in the category of unconventional oil and gas, is a kind of reservoir that hydrocarbon accumulate in the fracture which is under the impact of the tectonic movement and abnormal high pressure. Some scholars think that shale oil can be subdivided into narrow sense that is the mature oil in the shale and broad sense that is equal to the tight oil. Shale oil is a kind of petroleum accumulation that oil contain in the organic, lamination and nano-matrix pore of the shale under the effect of the hydrocarbon generation and expulsion, precipitation differentiation and the strata effect. What should be paid attention especially is that the shale hosted oil, which is used in the exploration field, is the mature oil contained in the oil-bearing shale, which is different from shale oil that is extracted from the man-made shale oil. According to petroleum geology theory and kerogen hydrocarbon generation theory, the

petroleum of the traditional structure reservoir, lithologic reservoir and stratigraphic reservoir ought to experience the second migration. So the petroleum of the traditional reservoir belong to the outside system. However, the oil of the shale hosted oil only experiences the primary migration, which belongs to the source system. The man-made shale oil extracted from the oil shale that is in-situ dissociated unconventional petroleum resource belong to the kerogen system.

The unconventional petroleum resource in the shale system is in situ reservoir, short distance migration or retention accumulation, which highlight the primary migration that is seldom studied in the petroleum geology. In other words, the process and mechanism of the hydrocarbon generation, primary migration, and hydrocarbon retention of the "hydrocarbon generation kitchen" should be emphasized. So shale petroleum system should be discussed and the formation mechanism and the space distribution of all kinds of unconventional petroleum resource in the shale formation should be studied systematically.

2 Case study from Chnag7 in Ordos Basin

According to the large amount of study, the unconventional petroleum resource in Chang 7 shale formation which includes oil shale, shale hosted oil, tight oil and shale gas embodied the characteristic of orderly accumulation. If the TOC of the oil shale is more than 6%, the target zone will not be favorable area of shale hosted oil because of the high efficient of kerogen network hydrocarbon expulsion(Cui Jingwei, 2013). The target zone where the TOC of dark mudstone is below 6% is the sweet pot of the shale hosted oil exploration. On the north side of the basin, high bearing-oil oil shale distribute in

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the Tong chuan and Bing Xian area where factories have been established to product man-made shale oil. Besides, continental shale gas is under exploration and development in Fuxian area, the most mature shale zone of Chang 7 in the lacustrine.

The result of the research of the Chang 7 shale system show that the petroleum resource in the system accumulates orderly. On the basic of the bury depth, TOC, and R_o , shale system can be subdivided into oil shale in the outcrop, fractured shale hosted oil in the middle depth, the shale oil for ICP, shale gas in the larger buried depth and the tight oil. The pertinent development technology will be employed to each kind of petroleum resource.

The first type of petroleum resource in the shale system is the oil shale in the margin of the basin. This kind of resource is located in the outcrop and shallow depth, the mature of which is low (depth<1000m) and oil content is high (>3.5%). The oil shale can be exploited outdoors and this approach is widely used in Estonia, Brazil, and China. Apart from the approach of China, PetroSix process of Brazil oil company, Kiviter process and Galoter of Estonia, Albert Taciuk Process, the most advanced approach is the EcoShale in international. This kind of process combines the surface and underground, the process of which is to marsh the oil shale, bury the particle under the ground and heat by steam (the temperature of the steam is 370°C) However, this process hasn't become a commercial application.

The second type of the petroleum resource in the shale system is the fractured shale hosted oil zone in the middle depth. The TOC of the shale is between 2% and 6%, the buried depth is between 1500m and 2500m and R_o is below 0.9%. The shale that match condition above can be fractured and exploration can be carried out. This kind of technology is widely used in domestic and oversea.

The third type of the petroleum resource in the shale system is the shale oil that organic content is high (TOC>6%) and that is moderate mature (R_o <0.9%) for ICP in the middle depth that is from 1000m to 2200m in the basin. Currently the Shell is the leader in this technology, ICP, in the world. Apart from the ICP, many companies, ExxonMobil, AMSO, IEI, are trying to figure out other approaches to develop the oil shale. The mainly disadvantages of the ICP is that the heating period is too long, energy consumption is too much and the development need seal layer. While, the advantages of ICP is that the production of ICP is light shale oil which is abundant in gas in relatively low temperature, which is convenient for secondary dispose. In one word, the

economy of oil shale exploit depend on the quality (oil content, TOC, hydrocarbon potential) and the method of development are large-scale horizontal well and volume fracturing technology.

The forth type of the petroleum resource in the shale system is shale hosted gas in much deeper zone in the basin and the maturity of shale is beyond 1.0%, and TOC>6%. The buried depth of two zones in the Chang 7 shale system in Ordos Basin is 1400m and 2200m-2500m respectively. Currently, shale hosted gas in the organic shale is developed by large-scale horizontal well and volume fracturing technology.

The fifth type of the petroleum resource in the shale system is tight oil in the basin. This kind of resource is in large-scale distributed sandbody which is adjacent to organic mature shale (R_o >0.8%) vertically. Xinanbian tight oil field is found in this area and there are many high production well in the Long dong area, which form a hundred million tons tight oil field. Large-scale horizontal well and volume fracturing technology are widely deployed in those areas.

According to the main controlling factory and distribution characteristic of all type of the unconventional petroleum resource in the shale system, the theory of orderly accumulation of hydrocarbon in shale system is put forward, make difference between petroleum system and orderly accumulation hydrocarbon and meaning of the theory and practical significance is provided. Base on the theory mentioned above, the stress of the effective determination between the petroleum system and continuous petroleum accumulation, grading evaluation, the development of pertinence technology, 3D exploration, and combination development of petroleum resource in the shale system is meaningful for the development of the petroleum resource in the shale system.

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